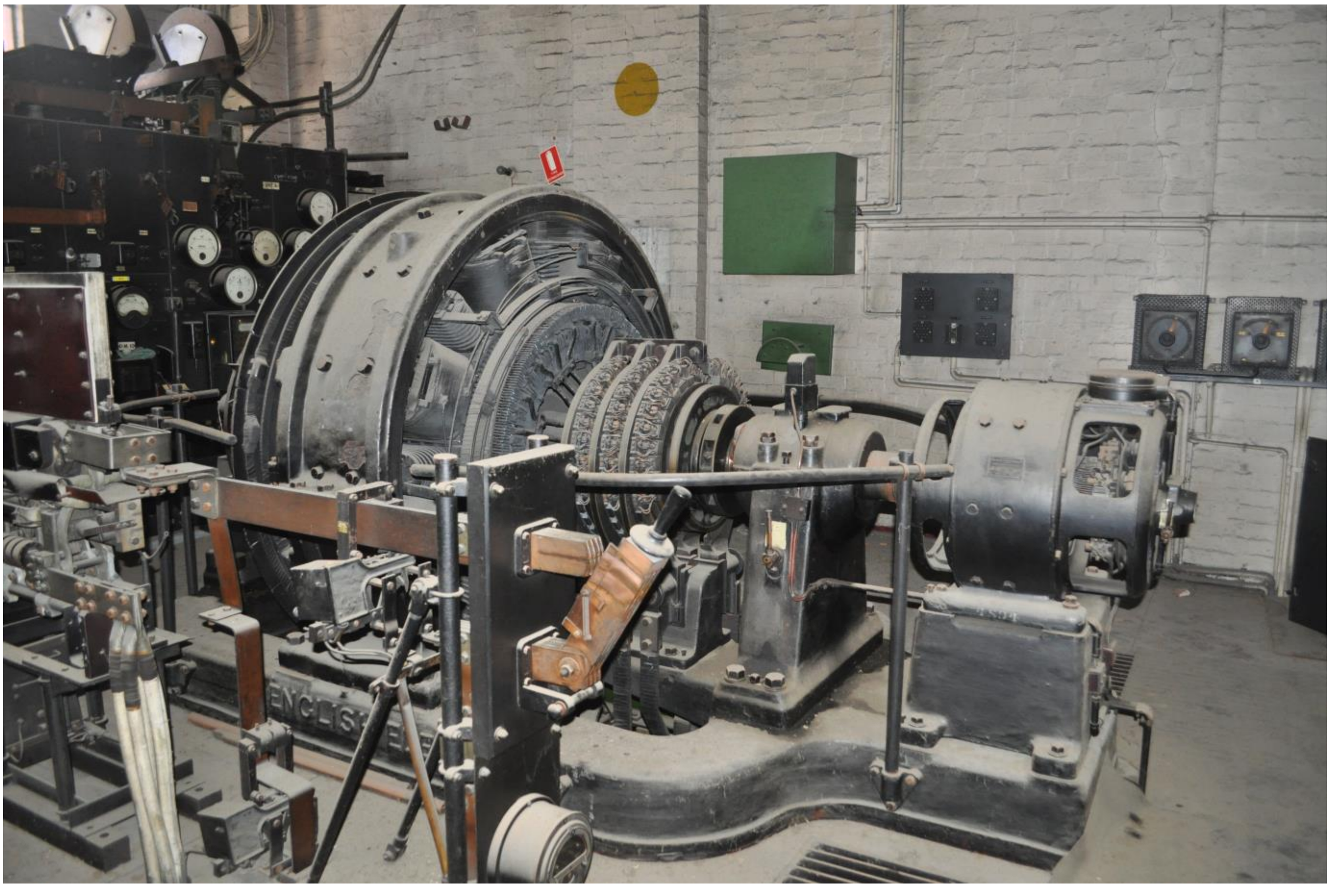
Engineers Australia

Engineering Heritage Victoria

Nomination

Engineering Heritage Australia Heritage Recognition Program

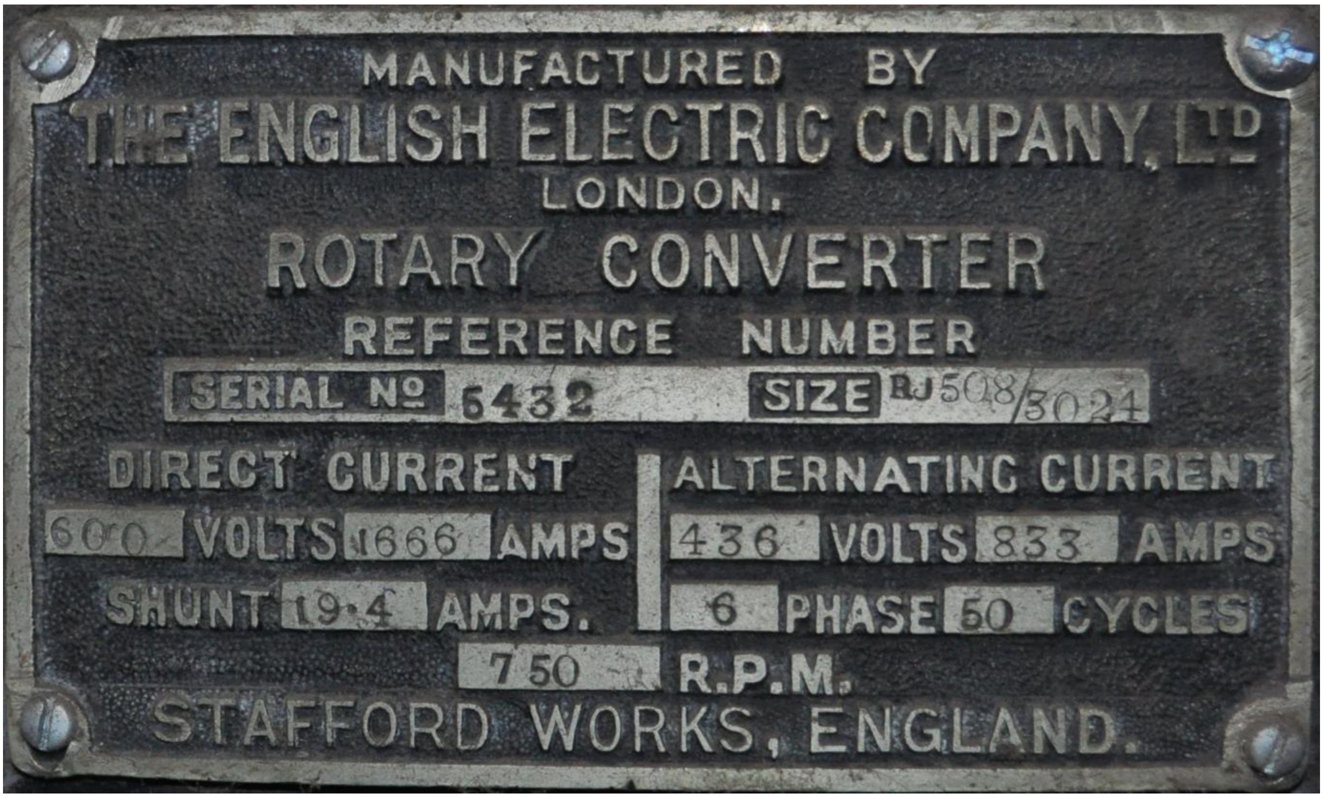
# MALVERN TRAMWAY SUBSTATION



April 2016

## *Front Cover Photograph Caption*

English Electric 1000 kW Rotary Converter. AC end of the machine with the exciter at the right hand end. See nameplate details below. Note that the AC voltage is adjusted to suit the desired 600 Volt output on the DC side. The unit transformer makes this adjustment. *Images: Owen Peake.*



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# 1 Introduction [1]

The Malvern Tram Depot was originally established by the Prahran & Malvern Tramways Trust (PMTT) in 1909/10. They installed motor-generator sets (single-phase AC motors driving DC generators) together with a large lead-acid battery to power their trams that initially operated along nearby High Street and Glenferrie Road.

The PMTT was taken over by the Melbourne & Metropolitan Tramways Board (MMTB) in 1920 and in 1929 a second car shed was erected together with a new substation building. The latter was located at the north-west corner of the original No.1 car shed and annexed a segment of it to contain the incoming high voltage alternating current switchgear. The substation building was designed by the then MMTB chief architect, Alan G Mansborough in the 'stripped Greek Revival style'.

The 1929 Malvern Tramway Substation remained in service until the late 1990s, a period of more than sixty years.

It is believed that the Malvern rotary converter traction substation has survived with its plant virtually complete due to the lateness of its retirement and the fact that replacement traction power semi-conductor rectifier substations were sited elsewhere. There evidently being no pressing need to either re-use the substation building or its site for other purposes.

[1] Pierce Miles. Report on Former Malvern Tramway Substation ('M'). Revision 2. October 2014.

# 2 Heritage Award Nomination Letter

The Administrator
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

**Name of work**: **Malvern Tramway Substation**

The above-mentioned work is nominated to be awarded an Engineering Heritage Marker or Engineering Heritage International Marker at your discretion.

The substation is located at the Malvern Tram Depot, Coldblo Road, Malvern, Victoria 3144. Coldblo Road runs west off Glenferrie Road between Stanhope Street and Union Street. Grid reference of the centre of the substation: 37.858664º south, 145.026858º east.

Owner: VicTrack, Level 8, 1010 La Trobe Street, Docklands, Victoria 3008. Mail address GPO Box 1681 Melbourne , Victoria 3001.

The owner has been advised of the intended 'virtual' nomination.

Access to site: The site is an operational Tram Depot used by the Melbourne tram operator contractor, Yarra Trams. The site is therefore not open to the public. Access must be specially arranged with VicTrack.

The Nominating Body for this nomination is Engineering Heritage Victoria

**David LeLievre**
**Chair**
**Engineering Heritage Victoria**

**Date: April 2016**

# 3 Heritage Assessment [2]

## 3·1 Basic Data

Other/Former Names: Nil
Location: Malvern Tram Depot
Address: Coldbro Road, Malvern Victoria 3144
Coordinates: 37.85865° S, 145.02686° E (UTM 55H 326416, 5808366m (WSG84)).
Melway Map 59, B-8.
Suburb/Nearest Town: Malvern
State: Victoria
Local Govt. Area: Stonnington
Owner: The former (1929) Malvern tramway substation ('M') is owned by VicTrack on behalf of the government of the State of Victoria. The operator using the Tram Depot is Yarra Trams under contract to the government of the State of Victoria.

Current Use: The substation is not being used. The Tram Depot remains in operation as a Tram Depot.
Former Use: Substation supplying 600 Volts DC to the local tram network.
Designer: Not known
Maker/Builder: Melbourne & Metropolitan Tramways Board (MMTB)
Year Started: 1929 (year of construction of the substation building)
Year Completed: 1929-1930
Physical Description: Substation converting 6.6 kV 50 Hz AC power from the electrical distribution system into 600 Volt DC power for electric tram traction use. Two 1000 kW rotary converters form the main machinery of the substation.
Physical Condition: In excellent condition. Although the interior of the substation is dusty and there is some storage of inappropriate materials the station appears to be ready to place in service with minimal work. The building appears to be sound and weatherproof.

## 3·2 Historical Notes

The original 1910 PMTT Malvern Depot included a motor-generator substation to supply 600 Volts DC for their electric trams. This substation was located further to the east of the present substation on the ground floor beneath the office accommodation and comprised a 'motor room' and an adjoining accumulator (battery) room. The PMTT substation was operated by the Melbourne Electric Supply Co. and supplied at 4000 Volts single-phase AC from their Richmond power station. The initial substation plant comprised two 100 kW motor-generator sets supplemented by a 220 Ampere-hour, lead-acid battery. By 1918 the combined motor-generator capacity had been increased to 1200 kW. Details of the original PMTT infrastructure including the motor generator substation and an interior photograph of same, are contained in Australian Mining and Engineering Review, 1910. Another photograph of part of this substation showing the booster set exists in the

[2] Pierce Miles. Report on Former Malvern Tramway Substation ('M'). Revision 2. October 2014.

former SECV's photograph collection held by Museum Victoria (scanned digital image no. 47274). The location of the former PMTT motor-generator plant and associated battery room is included in building plans reproduced in Allom Lovell, 1990.

The PMTT was taken over by the Melbourne & Metropolitan Tramways Board (MMTB) in 1920 and in 1929 a second car shed was erected together with a new substation building. The latter was located at the north-west corner of the original No.1 car shed and annexed a segment of it to contain the incoming high-voltage AC switchgear. The MMTB drawing No. 586, 'Alterations to Coldblo Road Depot Malvern and New Substation', shows in plan and elevations the general arrangement of the new substation building. Plans of the north side of the No. 1 car shed in Lovell Chen, 1990, show that in 1914 the area now occupied by the MMTB 1929 substation was a workshop precinct. It is understood that the 1929 substation remained in service until the late 1990s.

**Substation Electrical Plant and Equipment**

The 'new' (1929-30) traction substation contains the following main items:

- Incoming 6600 Volt, 3-phase (AC) switchgear housed in seven tall brick cells
- Two 1100 kVA oil/air cooled (ONAN) step-down main transformers with six-phase 436/218 V secondary windings
- Starting and AC control panels for the two rotary converters
- Two English Electric 1000 kW, 600 Volt DC rotary converter sets
- DC –ve side high-speed circuit breaker for each rotary converter set
- An open multi-panel switchboard with DC +ve side circuit breakers for the rotary converter feeds and for the outgoing trolley wire feeder circuits
- Other control gear including auto-control time switches and remote monitoring and control equipment.
- Field rheostats and current limiting resistors
- AC and DC power and control cabling interconnecting the various elements
- A station services switchboard supplied from two auxiliary 6600/415 transformers housed within the HV switchgear cells with automatic supply change-over
- A 100 kVA, 6600/415 V, ONAN type transformer also accommodated in transformer pit and believed to have supplied LV AC to the rest of the depot
- A facility for servicing rotary converter rotor commutators and slip-rings, including a small DC motor and gearbox for rotating the armature assemblies.
- Two 'spare' RC rotors (armatures), one set up in the servicing facility (one or both may have come from other decommissioned rotary converter substations).

The attached simplified AC and DC schematic diagrams (Appendix 1), based on observations during the 2014 site visits, indicate in schematic form the electrical connection of the main plant and equipment items.

The attached sketch plan shows the general layout of the substation equipment (Appendix 3). The rotary converters and their associated AC and DC switchgear, along with the rotor servicing facilities and a small office are located on an internal mezzanine floor with interconnecting and outgoing cables accommodated beneath. A manually operated overhead travelling crane runs east-west and would have facilitated removal and replacement of the heavy rotor assemblies in the two rotary converter sets. A loading bay in the north-west corner is accessed by a roller- shutter

door opening into Coldblo Road.

The rotary converters at this, and other rotary converter substations in the MMTB system, were arranged for normally unattended operation, with the pre-selected first or 'lead' machine being started and stopped prior to the first scheduled tram and after the last scheduled tram each day via a time switch. The second or 'lag' rotary converter would then automatically startup and shutdown based on the measured total DC demand with allowance for short-time variances. The substation was remotely monitored with some over-ride control functions from a Power Control Centre first set up by the MMTB adjoining its Carlton substation in Queensberry Street, Carlton, in the early 1930s and successively upgraded. Automatic unattended operation of large rotary converter plant was uncommon [3].

The rotary converters at the Malvern substation were started automatically in three 'steps', commencing at reduced voltage (50%) from taps on their supply transformer windings. Once the rotor had run up to speed acting as an 'inverted' induction motor via the damper windings, a motor driven cam switch connected the full AC voltage to the slip rings through series reactors to limit the switch-over inrush current. The cam switch then subsequently shorted-out the reactors. During this process, with the field windings energized, the rotor would pull into the synchronous speed of 750 rpm, as determined by the AC supply frequency – 50 Hz – and the number of stationary field poles – 8. A separate motor driven actuator was provided on each machine to automatically adjust the position of the DC brush-gear in response to the DC load for optimum commutation. (In a normally manned substation this was usually performed manually via a hand-wheel).

The 3-phase, 6.6 kV AC supply to the 'new' 1929 Malvern substation was provided via two underground feeder cables from the Glenferrie-High distribution substation by the State Electricity Commission of Victoria (SECV) who had by then taken over the former Melbourne Electric Supply Co and commenced extending high-voltage 3-phase supply into this hitherto single-phase supply area [4].

## 3.3 Heritage Listings

The whole of Malvern Tram Depot, off Glenferrie Road in suburban Armadale, is listed on the Victorian Heritage Register (VHR No. H0910). The 'Statement of Significance' in the latter listing records that the (tram) car shed No.1 dates from 1909-10 and was built by the former Prahran and Malvern Tramways Trust (PMTT), with a number of subsequent alterations and additions by the PMTT and, after 1919, by the Melbourne & Metropolitan Tramways Board (MMTB). The subject substation, erected by the MMTB in 1929, is included in the buildings listed in the Victorian Heritage Registration.

Name: Malvern Tram Depot
Title: Malvern Tram Depot
Number: VHR No. H0910
Date: Not known

[3] Steele. 1933.

[4] Smith. 1951.

# 4 Assessment of Significance

## 4.1 Historical Significance: [5]

Aside from the substation building which is already included in the VHR site listing, it is submitted that the still intact electrical plant as outlined above, is significant in its own right on a State basis, and also nationally.

The two 1930 vintage 1000 kW English Electric rotary converters are now rare survivors of this once common means of converting alternating current (AC) electricity supply to direct current (DC) for electric traction or public supply purposes. The fact that the two rotary converters are still in their original setting and virtually all the associated AC and DC switchgear and cabling, etc. is also extant, makes the substation especially valuable from an electrical engineering heritage perspective.

The 6.6 kV switchgear housed in individual brick cells, and the large open-panel 600 V DC switchboard with its heavy-current copper bus bars and single-pole DC air circuit-breakers, are significant in terms of being high quality representatives of this earlier form of electrical power engineering design and construction.

Whilst a single 500 kW rotary converter, its associated step-down transformer, reduced-current starter and a DC switchboard section remain at Yarra Trams' Brunswick Road ('B') substation – and are also worthy of preservation – they are no longer in their original positions and are not electrically interconnected. Communications by this author with Metro Trains' Traction System Engineer and CitiPower's Plant and Stations Manager has indicated that no plant of this type remains – in situ or stored - on their respective systems.

Interstate enquiries made by this author also indicate that no rotary converter substation with its electrical equipment still intact exist in other Australian States and that the once common large (500 kW and up) rotary converter machines were typically disposed of as scrap metal.

It is believed that the Malvern rotary converter traction substation has survived with its plant virtually complete due to the lateness of its retirement (understood as late 1990s); its replacement traction power semi-conductor rectifier substations being sited elsewhere; and there evidently being no pressing need to either re-use the substation building or its site for other purposes.

[5] Pierce Miles. Report on Former Malvern Tramway Substation ('M'). Revision 2. October 2014.

## 4.2 Historic Individuals or Association:

**Melbourne & Metropolitan Tramways Board (MMTB)** [6] [7]

In 1869 Francis Boardman Clapp set up the Melbourne Omnibus Company which ran horse-drawn omnibuses [8] in the inner suburbs of Melbourne. The company carried 4,990,077 passengers [9]. By 1882 the company had over 1600 horses and 178 omnibuses. In 1885 the company carried 11,659,937 passengers.

In 1885 Clapp's Melbourne Omnibus Company was granted a 30-year exclusive franchise for a cable tram network in Melbourne, with no competing lines being permitted. Clapp reorganised the company as the Melbourne Tramway and Omnibus Company (MTOC). A total of 15 lines were built, opening progressively between 1885 and 1991 [10].

The first foray into permanent electric tramways in Melbourne was made by the UK registered North Melbourne Electric Tramway and Lighting Company who in 1906 commissioned a steam power station in Mount Alexander Road Flemington for an electric tramway to serve Essendon and adjoining north-western suburbs from the Flemington Bridge cable tram terminus. The company also supplied electricity to paying customers in their franchise area for electric lighting via a three-wire DC distribution network. In 1907 the Prahran & Malvern Tramways Trust, a joint municipal undertaking, was established under an Act of the Victorian parliament. Subsequent legislation sanctioned the establishment of other municipal tramway trusts to own and operate electric tramways outside of the MTOC's exclusive licence area in inner Melbourne [11]. The Municipal Tramway Trusts were:

- Prahran and Malvern Tramways Trust
- Hawthorn Tramways Trust
- Melbourne, Brunswick and Coburg Tramways Trust
- Fitzroy, Northcote and Preston Tramways Trust
- Footscray Tramway Trust
- Northcote Municipality Cable Tramways

When the MTOC franchise ended in 1916, the entire operation of the Melbourne cable tramway system was handed over to the State government. The Melbourne and Metropolitan Tramways Board (MMTB) was formed in 1918 to take over the street tramways systems in Melbourne. It had the responsibility of operating all tramways within a sixteen kilometre radius of the Melbourne GPO, the only exceptions being the lines operated by Victorian Railways.

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[6] Melbourne & Metropolitan Tramways Board. Wikipedia. Last updated 25 December 2015.

[7] Brimson Samuel. The Tramways of Australia. Dreamweaver Books. Pp110-153. 1983.

[8] Brimson Samuel. The Tramways of Australia. Dreamweaver Books. pp110-153. 1983.

[9]Unknown. *The Melbourne Tramways and Omnibus Company*. Alexandra and Yea Standard, Gobur, Thornton and Acheron Express (Victoria 1877-1908). Vic: National Library of Australia). 14 December 1888. p 5. Retrieved 1 December2013.

[10] Keating J D. Mind the Curve – A History of the Cable Trams, Melbourne University Press. 1970.

[11] Pierce Miles. Early electricity supply and the introduction of electric trams in Australia. Engineering Heritage Australia Conference, Newcastle. December 2015.

### Takeover of tramways network

The MMTB commenced operations in 1919, taking over the cable tram network in 1919.

On 2 February 1920, it took over the six suburban electric tramway trusts, which were dissolved later that month. The MMTB also succeeded the Cable Tramway Board and the Royal Park Horse Tramway. The MMTB took over the North Melbourne Electric Tramway and Lighting Company on 21 December 1922, after the State Government bought the Company's interest in both the lighting and tramways undertakings.

### Conversion of cable system

The MMTB progressively converted cable tram lines to electric trams commencing in 1924, with the last Melbourne cable tram ceasing operation on 26 October 1940.

### Organisation

The MMTB was established under the *Melbourne and Metropolitan Tramways Act 1918* (No.2995). The seven members of the Board, including a Chairman and a Deputy Chairman, were appointed by an order of the Governor-in-Council dated 22 July 1919. The inaugural chairman was Alexander Cameron who had been chairman of the Prahran and Malvern Tramways Trust.

The MMTB was an independent statutory body which reported to the Minister of Public Works until 1952 and subsequently to the Minister of Transport.

### Chairman

Alexander Cameron, who was Chairman of the PMTT from 1908, was appointed as the first Chairman of the MMTB in 1919 and served in that role through to 1935.

Five people held the role of MMTB chairman from 1919 when the MMTB was established to 1983 when it was absorbed by the Metropolitan Transit Authority.

## 4.3 Creative or Technical Achievement:

Rotary converter traction substations were considered the norm for supply to electric tramways and railways at the time of installation of the Malvern Substation so that the technology was not particularly innovative. The quality of the installation was typical of that time with a great deal of attention to detail and very precise detailed design and installation being utilised. Such a high standard of construction was the norm in that period.

## 4.4 Research Potential:

The record of this particular technology from this period is poor. This installation if probably the last remaining installation of its type in Australia in a complete condition. Elsewhere empty buildings of substations remain (e.g. Victorian Railways rotary converter stations of a similar era) and in some cases individual items of equipment preserved but out of their original setting and context.

Hence there is an opportunity to research and record this installation in detail whilst it is still available for research. The future of the installation can only be regarded as ‘at risk’ as it is not currently protected by the Heritage Act and there is little regard to heritage protection amongst property developers, particularly in the last 16 years.

It is also important to research the survival of similar substations worldwide. Such research would inform and strengthen the case for those seeking protection of the Malvern substation.
This would be particularly true if it was found that there are very few such substations in preservation worldwide.

### 4.5 Social:

Tramway substations have always been beyond the sight of the general public.

Few people give any thought as to where the motive power for trams comes from and even fewer have any concept of the technology processes involved in making a high-power direct current supply available.

Nevertheless the Melbourne tram network, of which this substation formed just a small component, is and has been one of the  most effective forms of public transport in the city and has placed Melbourne ahead of many other major cities in the world. Generations of politicians, public administrators and tramway workers have made good decisions and acted with due diligence to form, operate and maintain the tramway system over nearly 150 years and have, in the process, provided a very useful contribution to the social fabric of Melbourne.

Most Melburnians have travelled by tram and many travel by tram every day. The early entrepreneurs of the Melbourne tramway systems would be amazed if they could come back and see the modern electric tram network, carrying vast numbers of passengers as it does, in comfort and safety and at a reasonable cost.

### 4.6 Rarity:

As detailed in section 4.1 above the Malvern Substation is thought to be the last remaining complete substation of the rotary converter type in Australia.

There may well be others remaining internationally however this remains to be researched as mentioned in section 4.4 above.

### 4.7 Representativeness:

The Malvern Substation is typical of the type of substation used for heavy electric traction during the period after the invention and commercialisation of the rotary converter and prior to the invention and commercialisation of the mercury arc rectifier.

### 4.8 Integrity/Intactness:

The intactness of the Malvern Rotary Converter Substation is extremely impressive. The station appears to be ready to be restarted after a bit of a clean-up of the considerable dust accumulated in the substation.

There is no sign of vandalism, graffiti or water damages from roof leaks.

Integrity of the site is also impressive. There are a few signs of modifications during the life of the equipment and these changes are not particularly obvious and involve changes to control wiring and associated fittings.

## 4.9 Statement of Significance: [12]

**What is significant?**

The essentially complete rotary converter substation plant and equipment that from 1930 to the 1990s supplied 600 volt direct current (DC) for electric trams. The key items are the two 1000 kW English Electric rotary converter machines, associated 6.6 kV switchgear, transformers, automatic starting and AC control gear and DC switchgear/switchboard.

**How is it significant?**

The former Malvern tramway substation electrical plant and equipment satisfies the following criterion for inclusion in the Victorian Heritage Register [13]:

CRITERION A
Importance to the course, or pattern, of Victoria's cultural history.

CRITERION B
Possession of uncommon, rare or endangered aspects of Victoria's cultural history.

CRITERION C
Potential to yield information that will contribute to an understanding of Victoria's cultural history.

CRITERION D
Importance in demonstrating the principal characteristics of a class of cultural places and objects.

CRITERION F
Importance in demonstrating a high degree of creative or technical achievement at a particular period.

**Why is it significant?**

The former Malvern tramway substation electrical plant and equipment is historically significant as the only known surviving example of an intact rotary converter substation in Victoria, and probably nationally, of a once dominant means of converting alternating current (AC) electricity supply to direct current (DC) for electric traction (trams and trains) and DC public electricity supply.

Electrical plant of this type facilitated the development of electrically operated public transport in Melbourne and several regional Victorian cities over many years but intact examples are now rare. It has the potential to assist in the understanding of the development of electrical plant and equipment for public transport purposes and as a previously dominant technology for AC to DC electrical power conversion and represents the maturity phase in the design and construction of rotary converter equipment.

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[12] Pierce Miles. *Application to nominate a place or object for inclusion in the Victorian Heritage Register (for the purposes of s.23 of the Heritage Act 1995).* 6 November 2014. pages 2-3.

[13] Refer to the following web page for details of these criteria: http://heritagecouncil.vic.gov.au/heritage-protection/criteria-and-thresholds-for-inclusion/

### 4.10 Area of Significance:

The Malvern Tramway Substation meets five criteria for State Significance under the Victorian Heritage Act. It would therefore comfortably meet the requirements of EHA for recognition as an Engineering Heritage Marker.

The Malvern Tramway Substation may meet the EHA requirements for an Engineering Heritage National Marker if further research indicates that it is the only remaining substation of its kind in Australia.

The Malvern Tramway Substation would meet the EHA criteria for an Engineering Heritage International Marker as the bulk of the main equipment in the station was imported from either the United Kingdom or the United States of America. Furthermore research may indicates that it is a rare survivor of this type of technology on an international basis.

# 5 Interpretation Plan

## 5.1 General Approach

This site is recommended as a Virtual Interpretation site for the following reasons:

- The Tram Depot (of which the substation is part) is an industrial site not open to the public. Visitors must be authorised and escorted by VicTrack staff who are located in the Melbourne CBD and hence must make a special trip to escort visitors. VicTrack staff make appropriate arrangements with the Tram Operator, Yarra Trams.
- Nothing of the internal equipment in the substation can be seen from outside the property perimeter fence.

Whilst some discussion has taken place about re-opening the currently closed Tramway Museum in Stanhope Street (just north of the Tram Depot proper) and making a tour of the substation a part of the visitor experience of the Tramway Museum this project is at an early stage and is contentious with some parties. It would also require re-arranging some fencing and security arrangements for the Tram Depot site to make access for visitors to the Tramway Museum and Substation available without entering the secure area of the Tramway Depot.

A ceremony is not therefore planned for this site and there would be no interpretation panel located on the site.

A web-based "story board" would however be designed for placing within the Engineering Heritage Register on the web page. This module would have similar characteristics to an interpretation panel i.e. a "virtual interpretation panel".

## 5.2 The Virtual Interpretation Panel:

1. A title "Malvern Tramway Substation".
2. Logos of Engineers Australia, VicTrack, Yarra Trams, Victorian Government (generic) to be incorporated.
3. A small scale representation of the EHA marker plate.
4. The date and other details of the recognition process.
5. Highly legible text.
6. Brief captions for each photograph including attribution.
7. Total text should not exceed 500 words excluding headings.
8. Sized to be compatible with electronic devices.

### 5.3 Possible Interpretation themes for Virtual Interpretation Panel

The following subjects have been assessed as possible themes for the interpretation panel:

1 The history of the Tram Depot and the Substation

2 How do Rotary Converters work??

3 How do we make DC to supply trams now??

# 6 References: [14] [15]


Allom Lovell. Heritage Report to PTC on Malvern Tram Depot and Hawthorn Tram Depot. Unpublished report.1999.

The Prahran – Malvern Electric Tramway. *Australian Mining and Engineering Review.* 7 June issue, 1910. pp 319 – 323.

Blalock T J. The Rotary Era – Early AC to DC Conversion. *IEEE Power & Energy Magazine.* Part 1 Sep/Oct and Part 2 Nov/Dec, 2013. [http://magazine.ieee-pes.org/septemberoctober-2013/history-9/ and http://magazine.ieee-pes.org/novemberdecember-2013/history-10/].

Brimson Samuel. The Tramways of Australia. Dreamweaver Books. Pp110-153. 1983.

Hill E P. *Rotary Converters – Their Principles, Construction and Operation.* Chapman & Hall.1927.

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Keenan. *Melbourne Tramways.* Transit Press. 1985. p26.

Pierce Miles. *Application to nominate a place or object for inclusion in the Victorian Heritage Register (for the purposes of s.23 of the Heritage Act 1995).* 6 November 2014.

Pierce Miles. Early electricity supply and the introduction of electric trams in Australia. Engineering Heritage Australia Conference, Newcastle. December 2015.

Pierce Miles. Report on Former Malvern Tramway Substation ('M'). Unpublished. Revision 2. October 2014.

Smith A H. The Development of the Metropolitan Distribution System (Eastern Portion) 1900 – 1950. Unpublished typewritten manuscript plus maps. SECV.1951.

Steele C L. A Supervisory Control System for Traction Substations - Equipment Designed for the MMTB. *The Electrical Engineer and Merchandiser*. 15 November 1933.

Vines G. Melbourne Metropolitan Tramway Heritage Study. Biosis Research. Unpublished. 2011.


[14] Pierce Miles. Report on Former Malvern Tramway Substation ('M'). Unpublished. Revision 2. October 2014.

[15] Entries are edited according to the Vancouver system. Refer to Commonwealth Government Style Manual for authors, editors and printers. Sixth Edition. Revised by Snooks & Co. 2002. page 190.

# 7 Acknowledgments, Authorship and General Notes

## 7.1 Acknowledgments

I wish to acknowledge my colleague Miles Pierce who prepared most of the documents which have been used to write this nomination. Miles is a long-time enthusiastic supporter of Engineering Heritage Victoria (EHV) and Engineering Heritage Australia (EHA). He still serves on the committee of EHV and is a past Chair. He has served a term on the National Board of EHA in the recent past. Miles is an electrical engineer of considerable professional standing and has a particular interest in electricity supply in general and electricity supply to tramways and railways in particular.

I also wish to acknowledge James Caws of VicTrack who are the owners of the Malvern Tram Depot (including the substation) who has shown considerable interest in the preservation of the substation. He has particularly assisted Miles Pierce and myself in arranging and escorting us on visits to the substation.

## 7.2 Nomination Preparation

This nomination was prepared by:

**Owen Peake**
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Email: owen.peake@bigpond.com

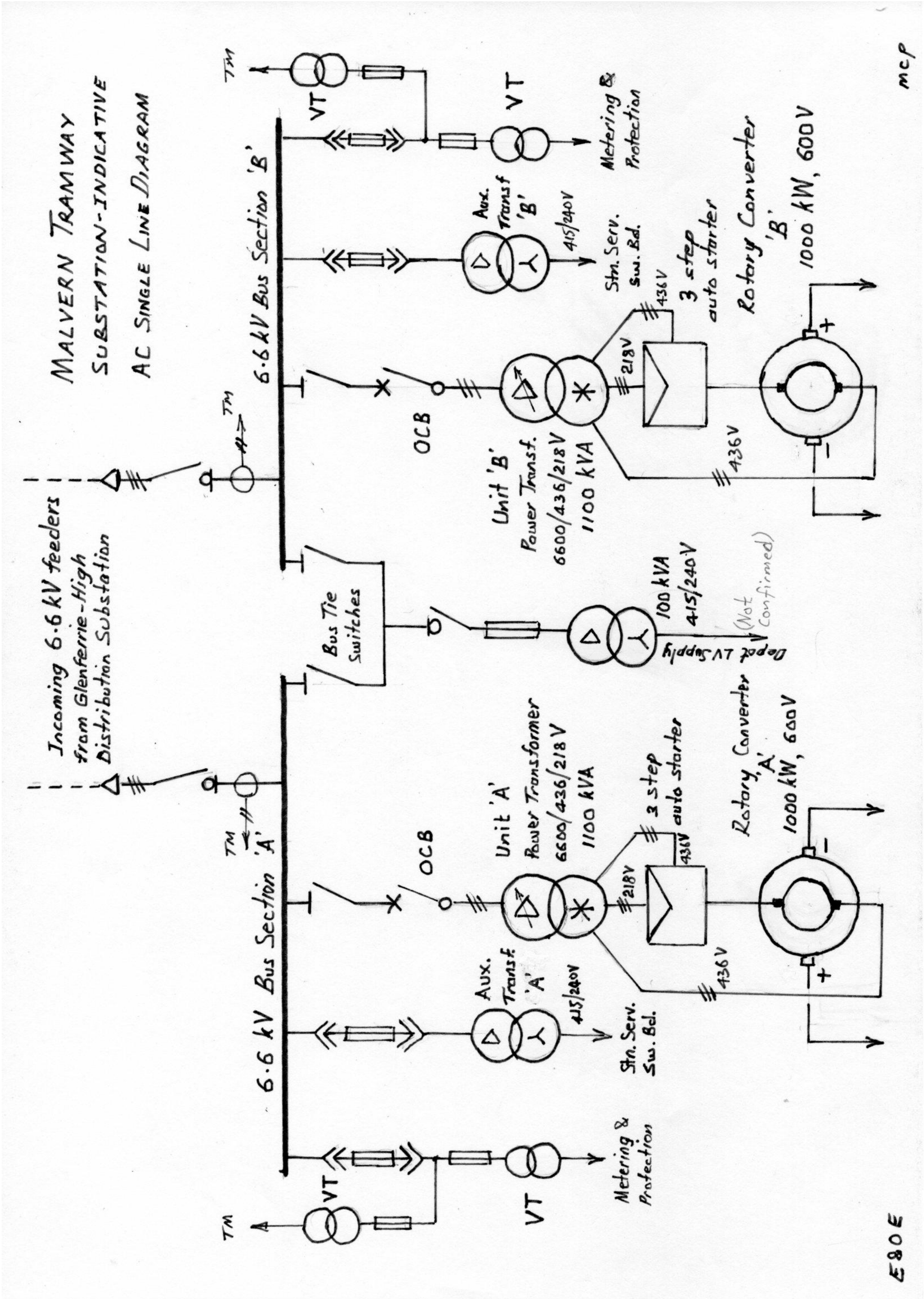
## 7.3 General Notes

This document has been prepared in accordance with the Commonwealth Government Style Manual for authors, editors and printers, Sixth Edition, revised by Snooks & Co, 2002.

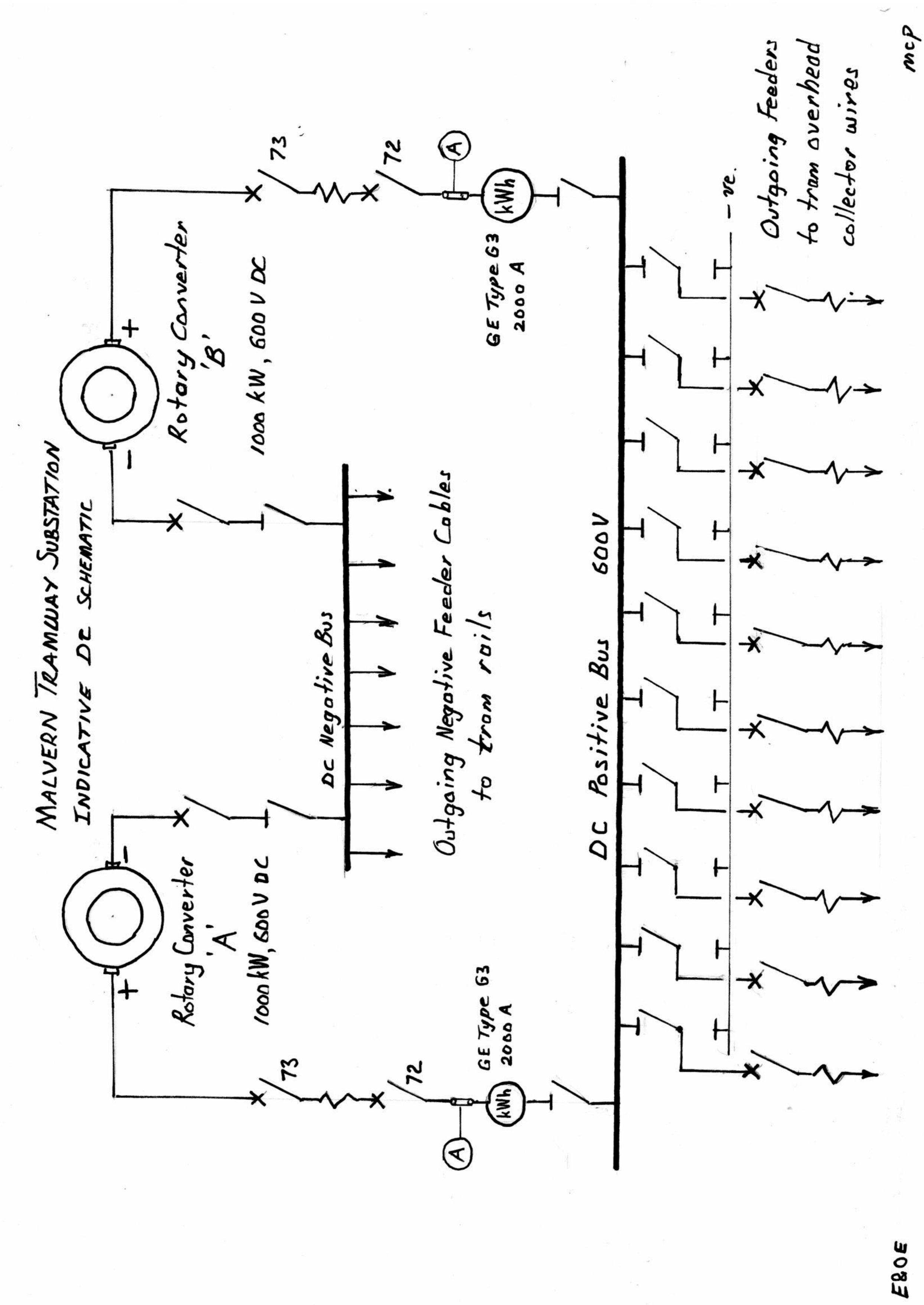
The method of citation used in this document is the Vancouver System. See page 190 of the above Style Manual.

[16] Electrical Engineering. 1964.

## Appendix 1: Schematic Electrical Diagrams




Indicative electrical AC single line diagram. *Sketch: Miles Pierce.*




**Indicative electrical DC Single Line Diagram.** ***Sketch: Miles Pierce.***

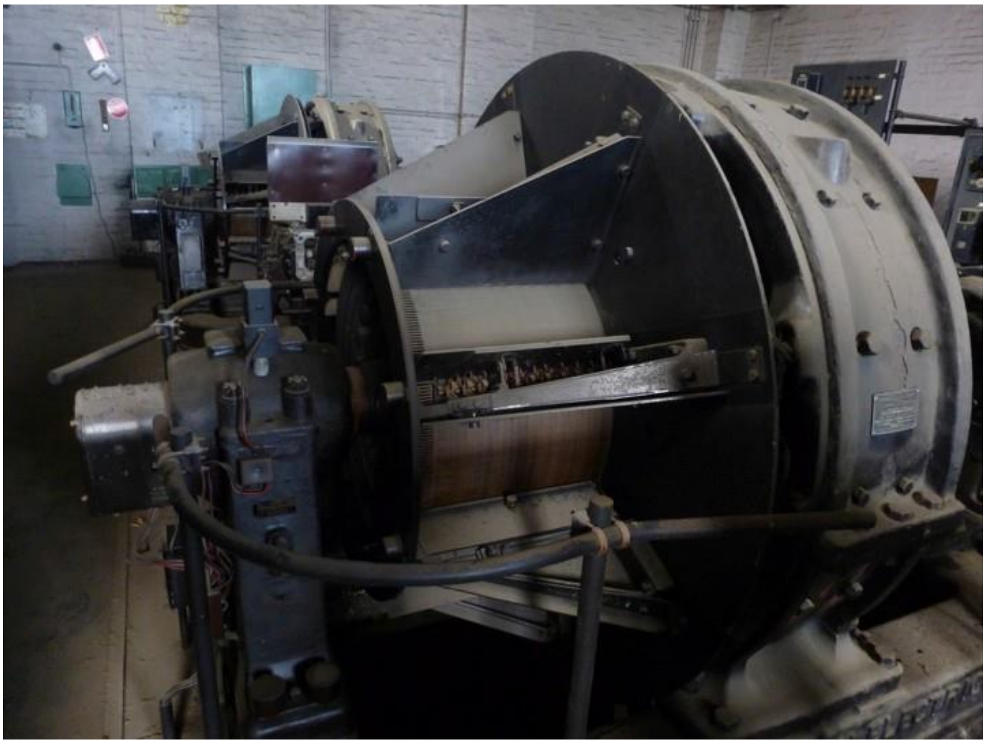
# Appendix 2: Images with Captions

**Interior view showing the two rotary converter machines and open panel DC switchboard.**
***Image: Miles Pierce.***

**Exterior (north) facade bordering Coldblo Road.** ***Image: Miles Pierce.***

General view of rotary converters and switchboard. *Image: Miles Pierce.*

AC end of 'B' rotary converter showing slip rings and exciter. *Image: Miles Pierce.*



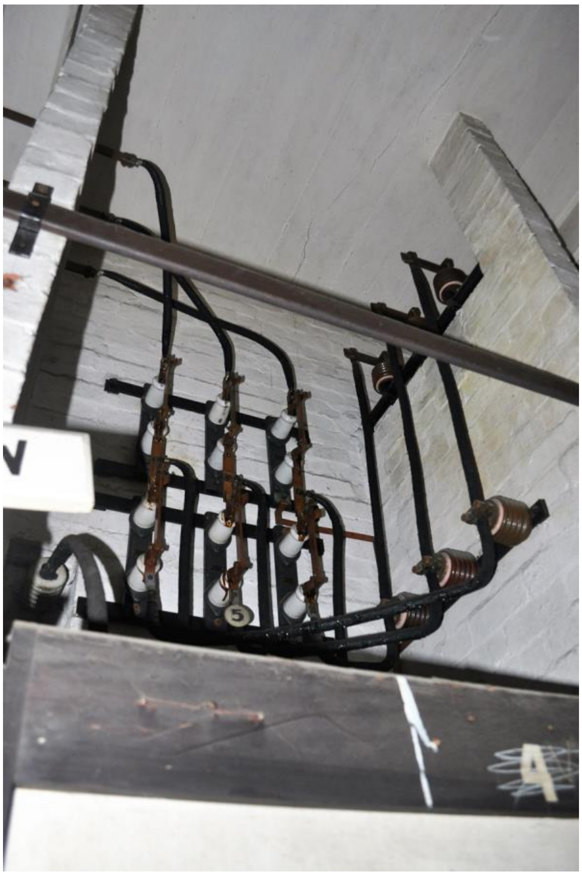
**DC end of rotary converter 'B' showing commutator. *Image: Miles Pierce.***

**DC (+ve) 600 Volt outgoing trolley wire circuit panels. *Image: Miles Pierce.***

**Rotary converter 'A' supply transformer.** ***Image: Miles Pierce.***

**Rotary Converter 'B' AC Control Panel.** ***Image: Owen Peake***

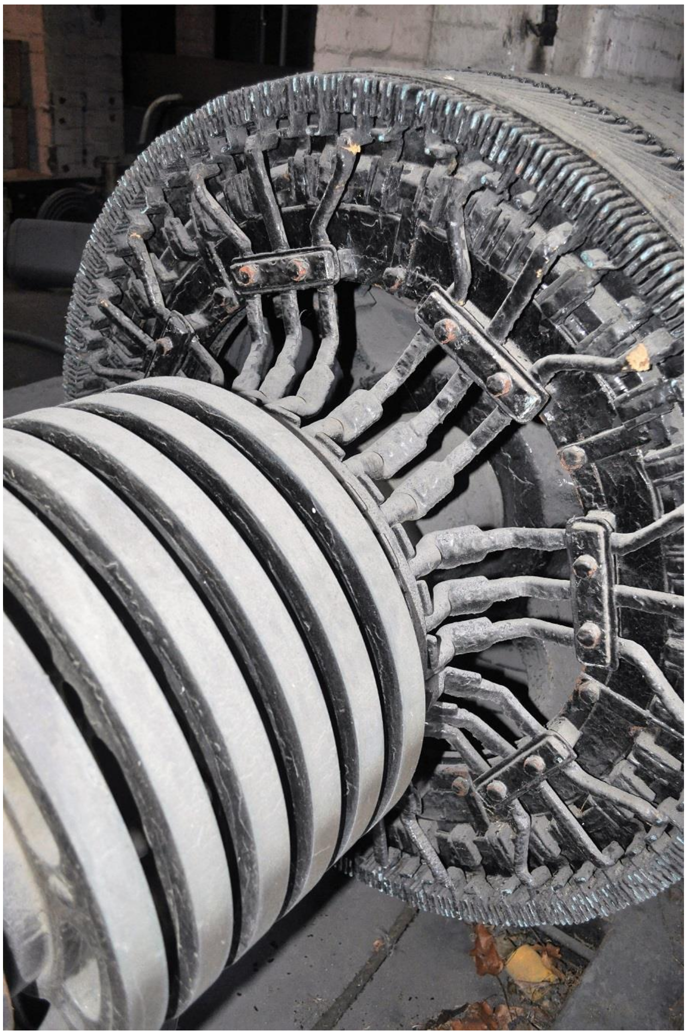
**6.6 kV AC circuit Breaker in brick cell.** ***Image: Owen Peake***



**6.6 kV AC busbars above Bus Tie panel.** ***Image: Owen Peake***

**6.6 kV Cable Gallery between the back of the AC switchboard cells (right) and the transformer bay (left). The circuit breaker operating mechanisms are in this space. *Image: Owen Peake***

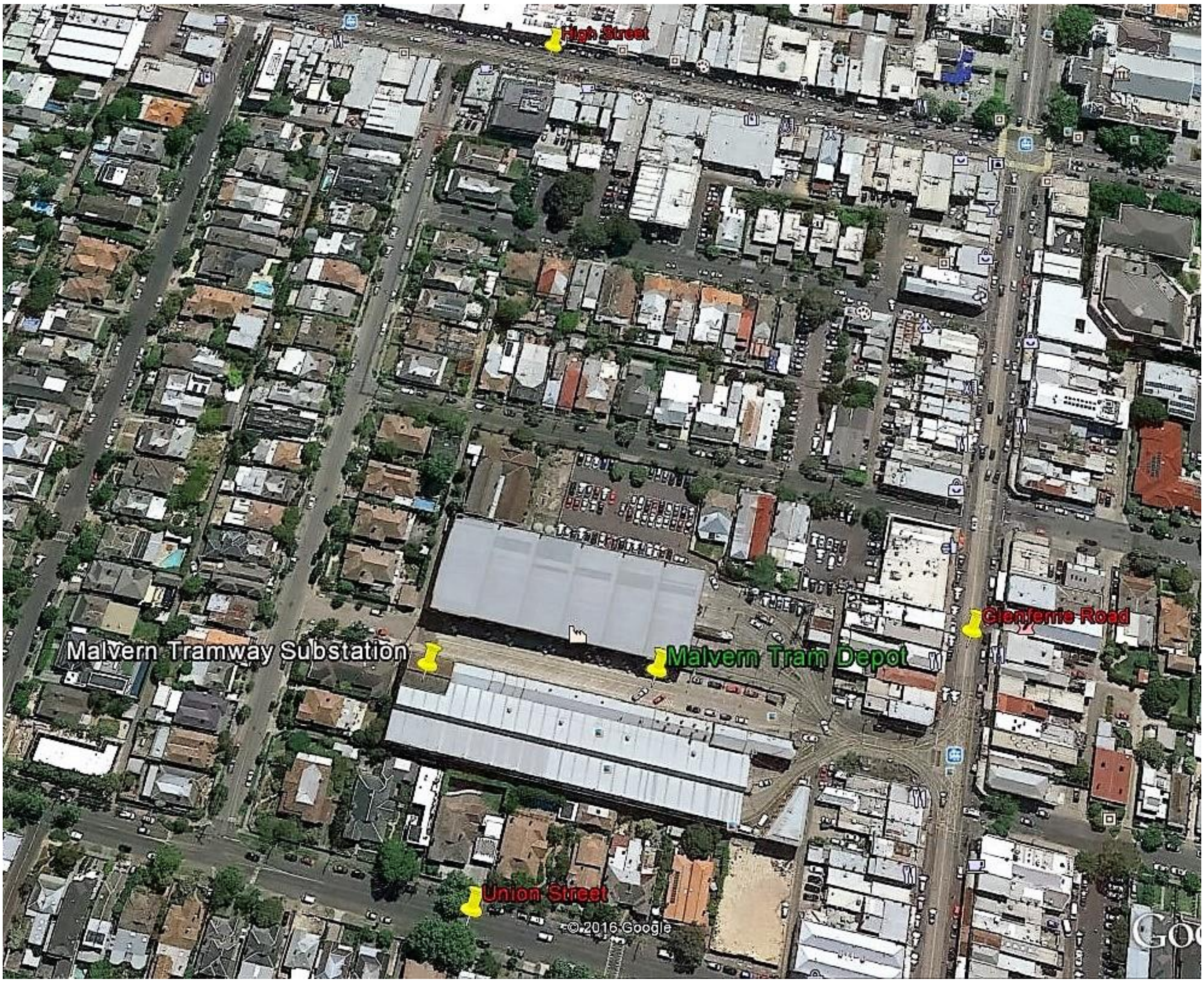
**Rotary Converter rotor with AC sliprings nearest camera and DC commutator at rear. *Image: Owen Peake***



Rotary Converter rotor detail of 6 phase AC slip rings. *Image: Owen Peake*

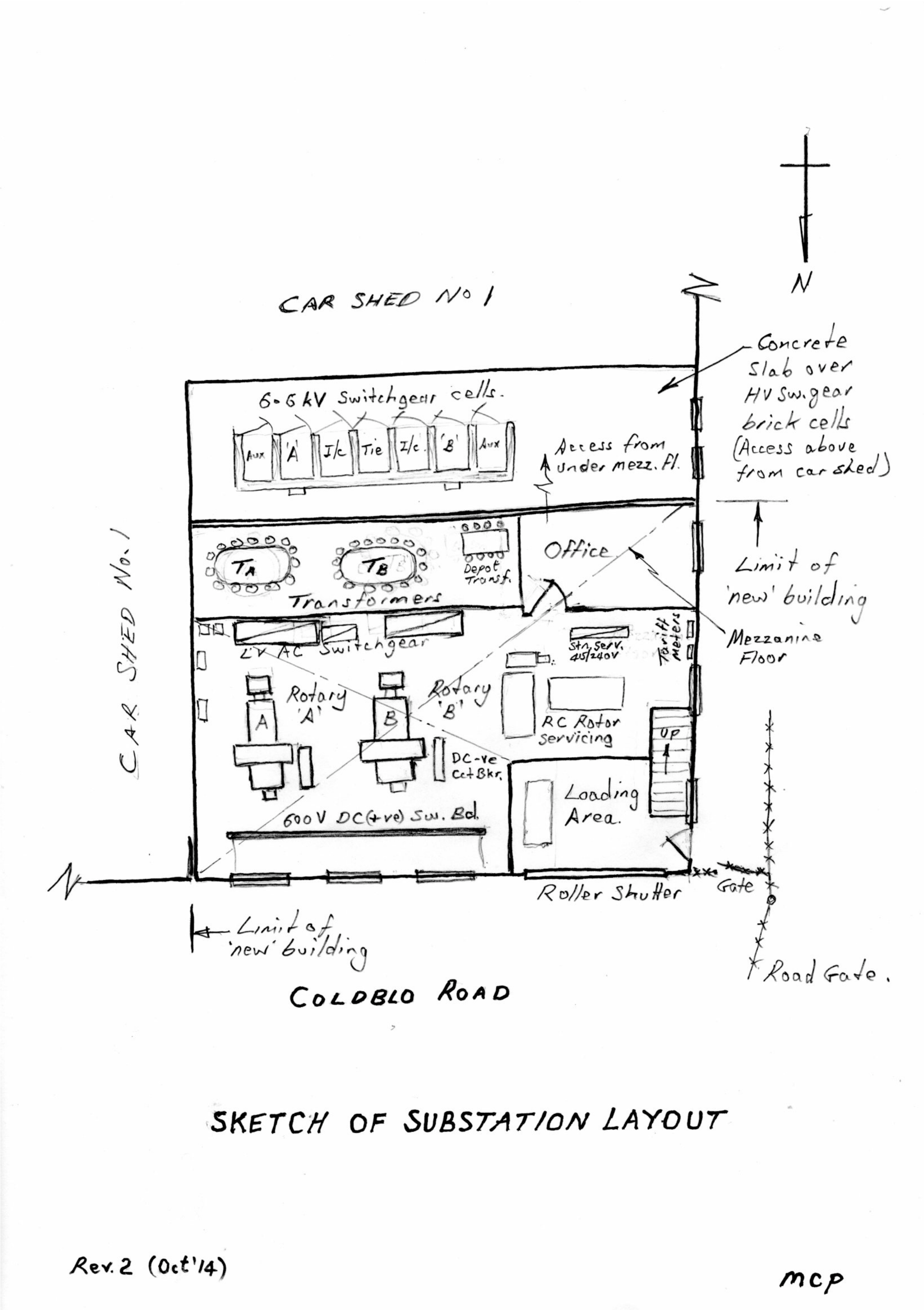
Rotary Converter rotor detail of DC commutator. *Image: Owen Peake*

## *Appendix 3: Maps*




**Malvern Locality Map. *Image: Google Earth***


**Aerial view of Malvern Tram Depot showing location of the substation in the bottom left sector of the image.** ***Air Photo: source unknown.***




Sketch of the substation layout. Note that north is at the bottom of the page. Note that the sketch depicts the major elements on the two level station. *Sketch: Miles Pierce.*

# *Appendix 4: Construction and Development of Rotary Converters*

Rotary converters are built like a DC generator with fixed, multi-pole, field windings – the stator component – and a rotating armature assembly with a conventional commutator and associated fixed brush-gear. The armature winding however is also tapped at intervals and connected to slip-rings at the opposite end to the commutator. It is fed from an alternating current supply via a step-down transformer whose secondary side voltage is selected to match up to the desired DC output voltage from the commutator. The two machines at Malvern were started at reduced voltage on the AC side (using their damper or 'amortisseur' windings) and a small separate DC generator on the end of the rotor shaft – the exciter - energized the stator field magnets [17].

The rotary converter was invented in the United States in 1888 and is generally credited to Edison employee, C S Bradley. It was further developed and perfected in the following decade. The rotary converter was superior in terms of space and efficiency to the then alternative arrangement of using an AC motor to drive a separate DC generator, by having only one stator and rotor assembly and one pair of shaft bearings. Its invention at the time of the 'battle of the systems': AC versus DC for public supply, was fortuitous when AC, due to its easy ability to be stepped up and down in voltage by transformers to suit transmission and distribution/end-use respectively, gained the ascendency, but by then many public electricity supplies in USA, UK, Europe, and Australia, were low-voltage direct current. The rotary converter in this context enabled electricity generation and transmission at high-voltage AC (and thus relatively low current and associated losses) with supply to existing DC distribution then afforded from rotary converter substations. This applied in both Melbourne and Sydney. The early superiority of series connected DC motors for electric traction – trams and trains – could also be accommodated from AC generation and transmission by then converting to DC locally using rotary converters [18].

## Rotary Converter Substations in Victoria

In 1900 the Melbourne City Council Electricity Supply Department (MCCESD) instituted a 460/230 V DC public supply in the CBD – particularly to supply electric lifts that were then becoming popular. Although initially supplied from steam engine driven DC generators at its Spencer Street power station, by early in the second decade of the twentieth century the MCCESD installed 6.6 kV AC steam turbine-generator sets at Spencer Street and established rotary converter substations around the CBD to maintain supply to the DC customers. The last MCCESD rotary converter substation was set up at Russell Place in 1929 – contemporary with the Malvern tramway substation. When the Melbourne suburban railways were electrified (the first electric train service commenced in 1919), the Victorian Railways established a number of large rotary converter substations fed at 20 kV, 25 Hz AC from their Newport power station, that converted the supply to 1500 V DC for electric traction. The City Council and the railways rotary converters were selectively replaced by mercury-arc rectifiers (glass bulb and/or steel-tank type) from the middle of the twentieth century, and more recently by successive generations of solid-state silicon diode rectifiers. Although many of the MCCESD and Victorian Railways former rotary converter substation buildings survive, none of the rotary converters and associated plant is known to have survived.

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[17] Hill. 1927.

[18] Blalock. 2013.

It is understood that in the case of the MMTB, quite a number of their rotary converter substations, including at Malvern, remained in-service until the 1990s. Keenan, 1985, lists nine rotary converter substations as at December 1984 and Vines, 2011, quoting Robert Green, mentions four tramway substations, including Malvern, with extant rotary converter plant in 2003. The machines were generally reliable if looked after, and as mentioned above, the MMTB installed controls to automatically startup and shutdown the rotary converter substations, and implemented a remote monitoring scheme enabling the substations to operate unmanned. Nevertheless, the Malvern substation is now the only remaining former Melbourne tramway substation with a complete rotary converter installation.

Electric tramways in Geelong, Bendigo and *[probably]* Ballarat, as well as in Melbourne, utilised rotary converters for their DC traction, but again most were ultimately scrapped and aside from Malvern substation, none remain connected up in their original position. This makes the intact rotary converter substation at Malvern tram depot, with its substantive 1000 kW machines and associated electrical plant and equipment, particularly valuable from a heritage perspective.

**MILES PIERCE**

# Appendix 5: EHA Magazine Article by Miles Pierce

### A Heritage Rotary Converter Traction Substation [19]

The former Malvern tramway traction substation attached to the still operating Malvern Tram Depot in Melbourne is a rare survivor from the time when AC-to-DC conversion for electric traction was performed by rotary converters. The Malvern tramway substation contains a pair of 1000 kW English Electric manufactured 600 volt rotary converter machines together with brick cell enclosed 6.6 kV incoming AC supply switchgear, step-down transformers, converter starting and control panels and a large open-panel 600 V DC switchboard. All are substantially intact, including interconnecting power and control cabling.

The Malvern tramway substation was constructed in 1929-30 by the then Melbourne & Metropolitan Tramways Board (MMTB). In 1920 the newly formed MMTB took over the assets of the former Prahran & Malvern Tramways Trust who established the original Malvern tram depot in 1909. This supplied electricity to the local tram network via a motor-generator set powered from the then Melbourne Electric Supply Company's 4.2 kV single-phase AC distribution.

The MMTB's Malvern substation was the last of many such rotary converter substations serving the Melbourne electric tram network, with its retirement only occurring in the 1990s. This late decommissioning date, along with its DC output subsequently being provided by new solid-state semi-conductor rectifier substations located elsewhere, has evidently accounted for its survival.

Rotary converters are built like a DC generator with fixed, multi-pole, field windings – the stator component – and a rotating armature assembly with a conventional commutator and associated brush-gear. The armature winding however is also tapped at intervals and connected to slip rings at the opposite end to the commutator. It is fed from an alternating current supply via a step-down transformer whose secondary side voltage is selected to match up to the desired DC output voltage from the commutator. The two machines at Malvern were started at reduced voltage on the AC side (using their damper or 'amortisseur' windings) and a small separate DC generator on the end of the rotor shaft – the exciter - energized the stator field magnets.

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[19] Published in EHA Magazine, Vol 2, No.1, January 2016.

distribution/end-use respectively, gained the ascendency, but by then many public electricity supplies in USA, UK, Europe, and Australia, were low-voltage direct current. The rotary converter in this context enabled electricity generation and transmission at high-voltage AC (and thus relatively low current and associated losses) with supply to existing DC distribution then afforded from rotary converter substations. This applied in both Melbourne and Sydney. The early superiority of series connected DC motors for electric traction – electric trams and trains – could also be accommodated from AC generation and transmission by then converting to DC locally using rotary converters.

The 1500 Volt DC suburban electric railway networks in both Melbourne and Sydney both initially employed rotary converter based substations, typically housed in large purpose built buildings located adjacent to the rail tracks. Similarly, electric trams that at various times – see separate article – plied the streets of all State capital cities and a number of regional centres from the 1890s onwards, also made wide use of the rotary converter to furnish their typical 600 V DC traction power. By the middle of the twentieth century, mercury arc rectifiers, both the glass bulb and steel tank varieties, became available in larger ratings and with their low maintenance and higher conversion efficiency superseded the 'rotaries'. More recently, they in-turn have been displaced by solid-state semi-conductor rectifier assemblies that offer even higher conversion efficiency and compactness.

Whilst many substation buildings that formerly were erected to house rotary converter plant for public DC supply and for tram or train traction purposes remain in situ – sometimes still in use with modern conversion plant or converted for other uses – the intact rotary converter plant at the Malvern tramway substation is a rare survivor. Interstate inquiries by the author have not revealed another example in Australia. Indeed, surviving large rotary converter machines themselves appear to be rare items in Australia with most having ended their life as a source of scrap metal.

In view of the evident uniqueness in Victoria, and possibly nationally, of the essentially intact rotary converter plant at the former Malvern tramway substation, an application has been lodged with Heritage Victoria for it to be added to the Victorian Heritage Register. The 1929 substation building is already on the VHR as a part of the Malvern Tram Depot, but current interpretation of the Victorian heritage legislation does not confer coverage of internal fixed plant and equipment.

**MILES PIERCE**

# *Appendix 6: Explanatory Breakout Boxes to Accompany Miles Pierce Article in Appendix 5.* [20]

## Alternating Current (AC) vs Direct Current (DC)

In the early days of public electricity supply there was a fierce competition between proponents of AC and DC. In the end AC won the competition but by that time there were a mixture of AC and DC supplies to customers in many countries.

Today most supplies to customers from utilities are AC but DC is used for many applications both within electricity systems and within customer premises. For example very large scale transmission of electricity is usually accomplished with High Voltage Direct Current (HVDC) lines and cables with voltages up to 1 million volts (1000 kV). These days many household appliances such as computers and other electronic devices operate on DC but they are supplied with AC from the household supply then converted into DC.

## Supply to Electric Trams (and Trains)

Until recently electric trams and trains were supplied with DC power from an overhead pickup wire or from a conductor laid like a “third rail” at ground level. This DC is either generated in a dedicated railway or tramway power station (uncommon these days) or AC from a supply utility is converted to DC in a converter station of which the rotary converted station described in this article is an example.

The electric propulsion of trains and trams was best suited to series connected DC motors which were rugged and provided admirable power/torque characteristics.

Things are more complex today as sometimes AC is supplied to the train (not trams in most cases) and sometimes the motors are AC using a variable-frequency electronic converters mounted on the train. Nevertheless the use of DC systems for trains and trams continues with solid-state converters used to supply networks.

## Conversion – AC to DC and DC to AC

As described in the paper DC supplies for trams and trains were converted by motor-generator sets; rotary converters; mercury arc rectifiers and solid state electronic rectifiers (converters) as these technologies progressed sequentially during the 20th century. Since the development of solid-state electronic devices it is just as easy to convert from AC to DC (termed a rectifier) as it is to convert from DC to AC (termed an inverter) opening up many clever engineering solutions. Now we regard any converter that isn’t solid-state electronics as engineering heritage!

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[20] Peake Owen. *Explanatory Breakout Boxes to Accompany Miles Pierce Article.* 10 November 2015. Not previously published.

## *Appendix 7: Details of the DC Switchboard*

The DC switchboard in the substation is an excellent example of conventional open panel type construction with indicating instruments, operating handles for circuit breakers, protection relays and, in this case, the busbar and knife switches for isolation on each panel. The mounting of the switches on the front of the panel, in full view, provides precise indication of open/close position right in front of the operator.

The structure of the switchboard consists of an open steel frame supporting panels of slate [21] that act as the insulator for equipment mounted on the switchboard and each item of equipment is bolted to either the front or rear of the panel.

Switchboards of this type are no longer considered safe in Australia because they did not incorporate positive methods of preventing contact with live electrical parts [22].

This type of switchboard required electrical fitting skills which are no longer available in the trade and most heavy switchboards are now of the metal-clad type and are factory-produced items requiring only minimal on-site electrical fitting.

The significance of this switchboard lies in two main areas:

- The rarity of this type of switchboard in recent decades. Preservation of some examples to show how they were constructed is important for training of tradesmen, technicians and engineers.
- The demonstration of very high level of expert trade skills demonstrated in such switchboards. Such fitting work would have involved large teams of expert electrical fitters supported by many apprentices and overseen by eagle-eyed foremen with vast experience.

The following images shows details of this switchboard construction noting some of its outstanding features:

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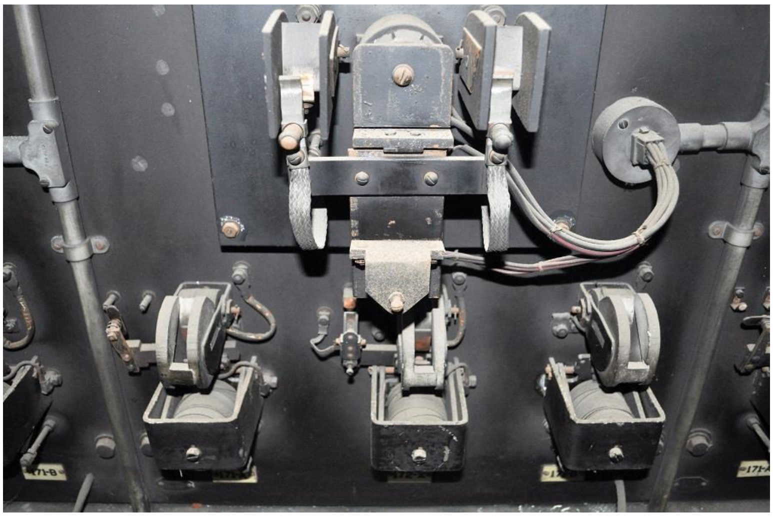
[21] The exact nature of the material forming the panels of the switchboard is still to be confirmed. Whilst the material looks like slate, which was one of several types of material used for this purpose, an expert inspection would be advisable.

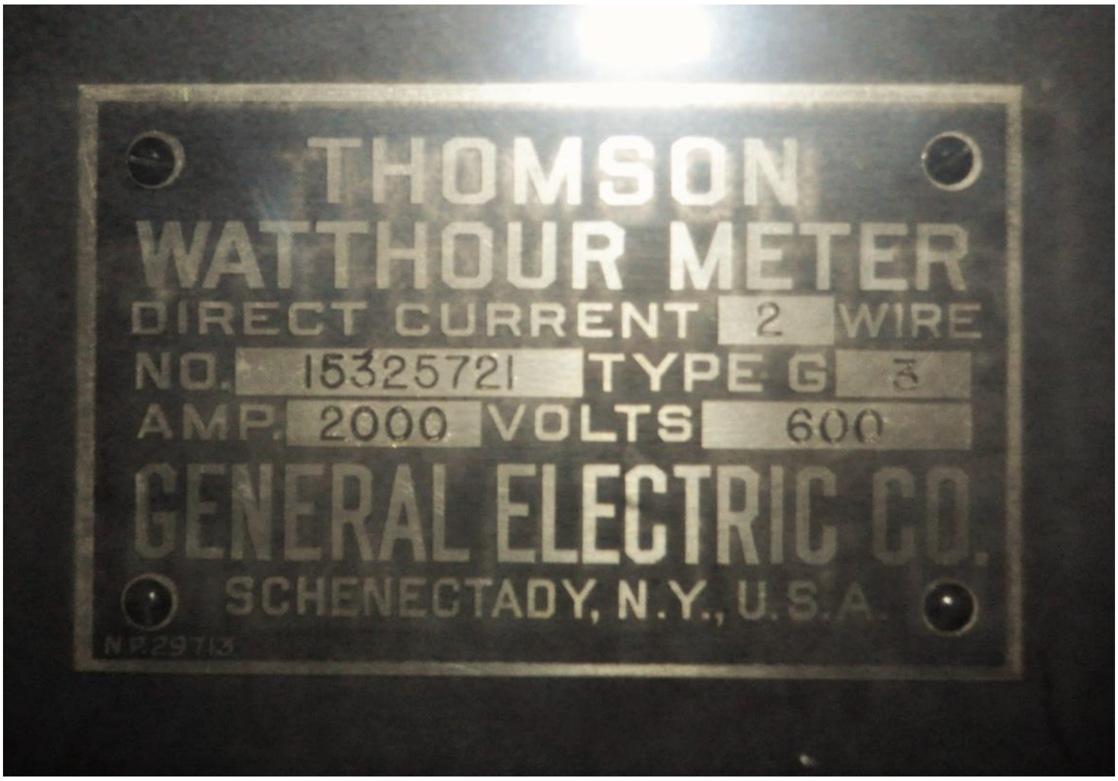
[22] The relevant Australian Standard (AS3000) does allow open switchboards under certain strict conditions.


**Section of the outgoing feeder section of the DC switchboard.**
**At the top of the image are the beautifully crafted knife switches**
**with connection to the positive (connection to overhead trolley wire) busbar at the top and negative (earth potential to connect to the tram rails) running along the face of the switchboard panel.**
**The centre part of the panel contains the protection relays and an ammeter for that circuit. The lowest panel has auxiliary contactors.**
***Image: Owen Peake.***



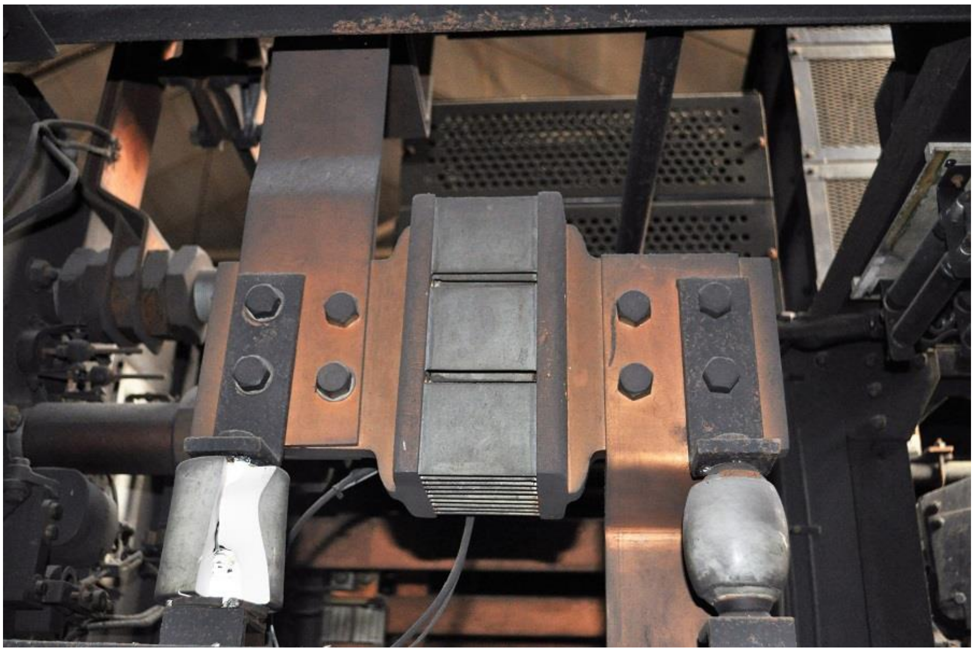
**Auxiliary contactors at the bottom of each panel.**
**The wiring in steel conduit is probably a later addition.**
***Image: Owen Peake.***


**General Electric 2000 Amp Whole-of-current Kilowatt-hour Meter for measuring the energy delivered from one of the two rotary converters.**
**The use of a whole-of-current meter of such a size these days is almost unimaginable!**
***Image: Owen Peake.***

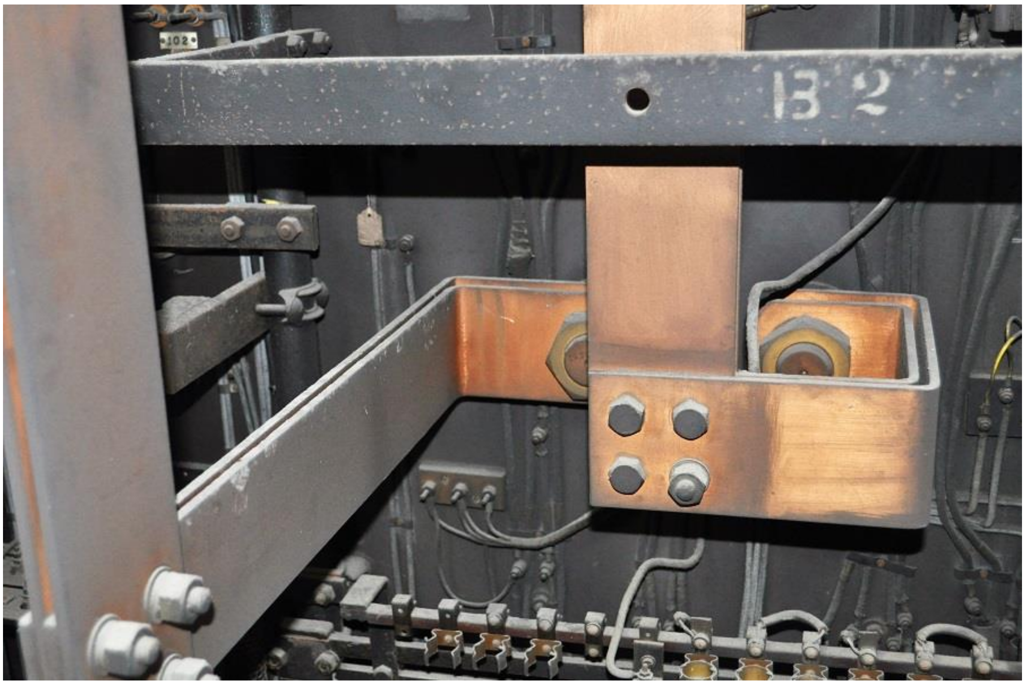



**Nameplate of the 2000 Amp Whole-of-current Kilowatt-hour Meter.**
***Image: Owen Peake.***

**Close view of the knife switches for isolating the circuit breaker at the rear of the panel from the busbars. The negative (earth potential) busbar runs along the face of the switchboard in this view. The small white box is apparently a modern relay forming part of a station remote control system. *Image: Owen Peake.***



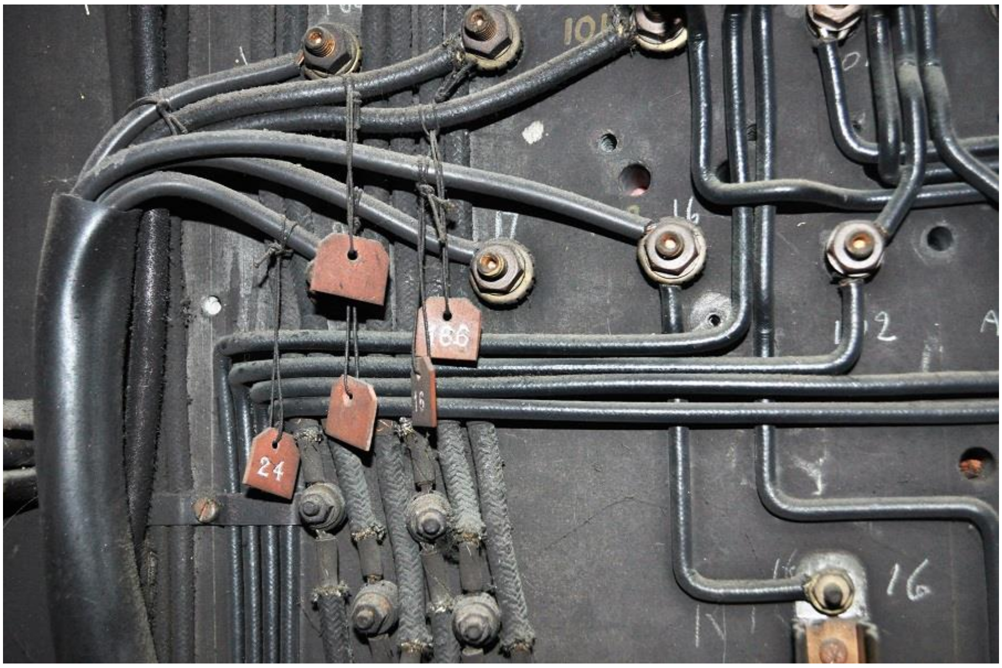
**2000 Amp Shunt presumably providing an output representing ‘current’ for indication and protection purposes. Note the damaged post insulator on the left hand side. This is one of the few examples of wear-and-tear seen in the station which was massively constructed and clearly designed for a very long life. The station was in service for around 60 years!**
***Image: Owen Peake.***



**Heavy copper busbars at the rear of the incoming panel from one of the rotary converters. This section of busbar provides current to the Kilowatt-hour Meter pictured earlier from the front. Workmanship of this high quality reflects the trade standards of the 1920s.**
***Image: Owen Peake.***

**Row of ten outgoing feeder circuit breakers. An open air circuit breaker of this type would produce a frightening flash on opening. The black arc chutes at the top of the image are designed to contain the arc and break it into sections to interrupt the current.**
***Image: Owen Peake.***

**Part of the mechanical linkages of the DC circuit breaker.**
**Auxiliary switches operated by the circuit breaker can be seen at right.**
***Image: Owen Peake.***




**Auxiliary wiring at the rear of the switchboard panel.**
**Note the wire number tags attached to some of the cables to assist in determining the function of the particular wire. Wiring of this type was designed for a long life but was difficult to modify as no slack was provided in the wiring.**
***Image: Owen Peake.***

**Resistances used in protection and metering circuits at the rear of a panel.**
***Image: Owen Peake.***

## *Change Control*

| CHANGE CONTROL | | | | |
|---|---|---|---|---|
| VERSION 1 | 23 FEBRUARY | 2016 | 1237 WORDS | COMMENCED DRAFTING |
| VERSION 2 | 14 MARCH | 2016 | 3406 WORDS | DRAFTING |
| VERSION 3 | 30 MARCH | 2016 | 7955 WORDS | DRAFTING |
| VERSION 4 | 5 APRIL | 2016 | 8101 WORDS | INCORPORATED COMMENTS FROM MILES PIERCE |
| VERSION 5 | 10 APRIL | 2016 | 8126 WORDS | MODIFIED IN LIGHT OF COMMENTS BY MP ON 7/4/2016 |
| VERSION 6 | 11 APRIL | 2016 | 8126 WORDS | MODIFIED IN LIGHT OF COMMENTS BY MP ON 11/4/2016 |